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DEPARTMENT OF PHYSICS
UNIVERSITY OF VIRGINIA
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CHARLOTTESVILLE, VIRGINIA

NASA CR70719

Status Report #5

Period Ending: November 30, 1965

Grant No.: NsG-455

Contractor: University of Virginia

Charlottesville, Virginia

Authors of Report: K. Ziock

R. C. Ritter

Department of Physics

Status Report

NsG-455

General Information:

Personnel

Two faculty members - the principal investigators - worked part-time on the project. The development of a large volume solid state detector was assigned to a graduate student as a Ph.D. thesis.

One instrument maker and one electronics technician were working halftime on projects connected with the grant. One electronics technician spent halftime during the report period.

Introduction

The research program outlined in our original proposal [1)] foresaw a multipronged attack on some of the then outstanding problems of detector development. Since that time the central importance of Li drifted Ge detectors for high resolution nuclear spectroscopy as well as for pion and muon physics has emerged dramatically; and in view of the encouraging success reported previously [2)] we have concentrated our efforts during the report period on the development of large volume annular Li drifted Ge detectors.

Progress Report

Solid State Properties of Importance to Detector Development:

The originally proposed investigation of solid state properties and effects that might be of importance to the development

1) A Research Proposal for Development of Particle Detectors. University of Virginia, December 17, 1962

2) Grant NsG-455, Status Report #4, May 31, 1965

of new particle detectors had been postponed in view of the then pending expansion of the low temperature facilities of this department. This expansion is still under way and a new low temperature laboratory totalling 2200 square feet is being constructed for occupancy this spring. The department has also materially added to its faculty strength in the area of low temperature physics. Under these circumstances we have decided to postpone a further experimental study of the interaction between ionizing radiation and superconducting junctions until our new laboratory with its greatly improved facilities will be available in spring. In the meantime, a theoretical study of the problem is being made by Dr. M. Zuckermann of this department.

Large Volume Li Drifted Ge Detectors

General Information:

Since one of us, R. Ritter, first proposed [1)] to increase the useful volume of a Li drifted Ge detector by drifting concentrically into the outer wall of a hollow Ge cylinder, another group has pursued a similar idea and produced large irregularly shaped "co-axial detectors."

Compared with these detectors, the truly co-axial detectors, henceforth called annular detectors, developed in the meantime under this grant, have some distinct advantages which we discuss in detail in this report.

Also, in the meantime, serious material problems have arisen at Sylvania, the sole U. S. supplier of detector grade germanium. Several users state that their failure rate in the manufacture of Li drifted Ge detectors, as a result of this, has risen to more than 90%. In two attempts (with material from two different batches), we have made two successful annular detectors. We think that we now understand the true nature of these defects in the material, and we will demonstrate below that they are of no detrimental influence in the manufacture of our annular detectors. This gives hope that the true annular configuration will avoid most of the present material problem, and may permit the use of poorer material which can be grown in larger ingots.

During the report period, work at the Chalk River (Canada) Laboratory has led to the introduction of successful liquid cooling, which allows better control and higher temperature during the drifting, so that the drift rate is increased. This method is being installed here. Coupled with the annular drifting it will be used in attempts to make detectors of up to 150 cm^3.

Work Performed During the Report Period:

In this report period work in this laboratory has involved the development of improved techniques, and the fabrication and testing of two annular detectors.

Development of New Techniques:

a) During our work, we have made extensive use of the spark cutting facilities of this department. To our knowledge this is the first time that Ge detector crystals have been spark cut, and the results have been very gratifying. Not only did the expected reduction in damage of the cut edge occur as demonstrated by greatly reduced bubbling in the following etch; we also found that the spark cut ends of the cylinder clearly show the depth of the Li diffusion. (see below)

b) A computer program was written which provides the necessary information to completely predict and control the diffusion process. The radiant heating method, first developed here for detector work, has been improved and fully instrumented as an adjunct to the programmed diffusion. Spark-cutting of the ends shows the exact depth of the diffusion (See Figure 1). From these tests, we believe that the programmed diffusion procedure is capable of depths controlled to $\pm$ 0.1 mm. As the amount and depth of diffused lithium is expected to have a strong bearing on drift depth limitations for very large detectors, we have given this problem considerable emphasis.

c) The danger of using gallium-metal contacts, as we had been doing, was pointed out to us by Chasman [2]. Since then, we have gone back to indium contacts. New cooling blocks were devised for drifting, and are shown in Figure 2.

d) Contrary to opinions given to us by several other workers in this field, drifting in a vacuum seems to be inferior to drifting in a dry nitrogen atmosphere. Figure 3 shows one test of

2) L. Chasman, private communication

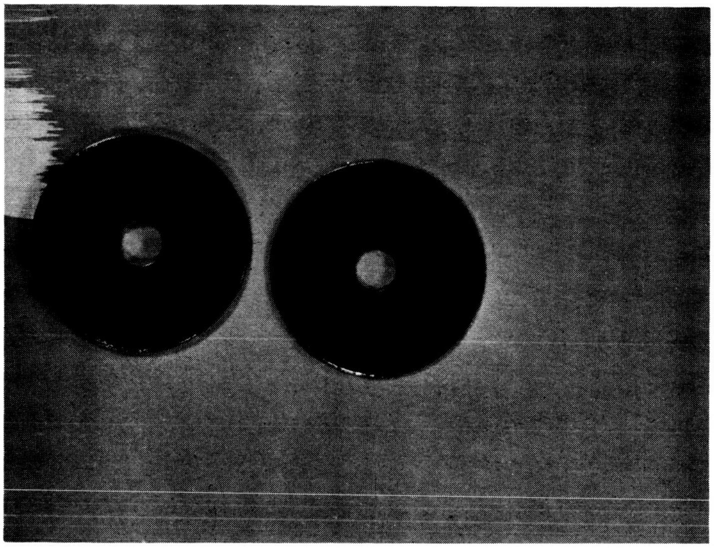


Fig. 1. Spark-cut ends of annuli after diffusion, before drifting.

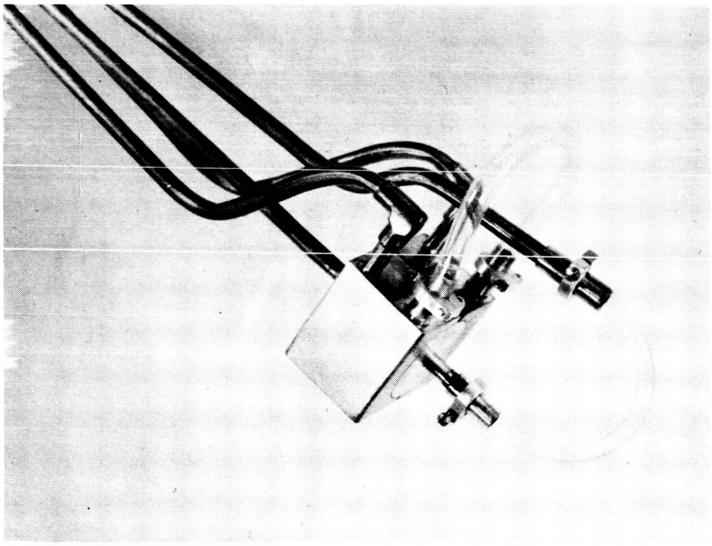
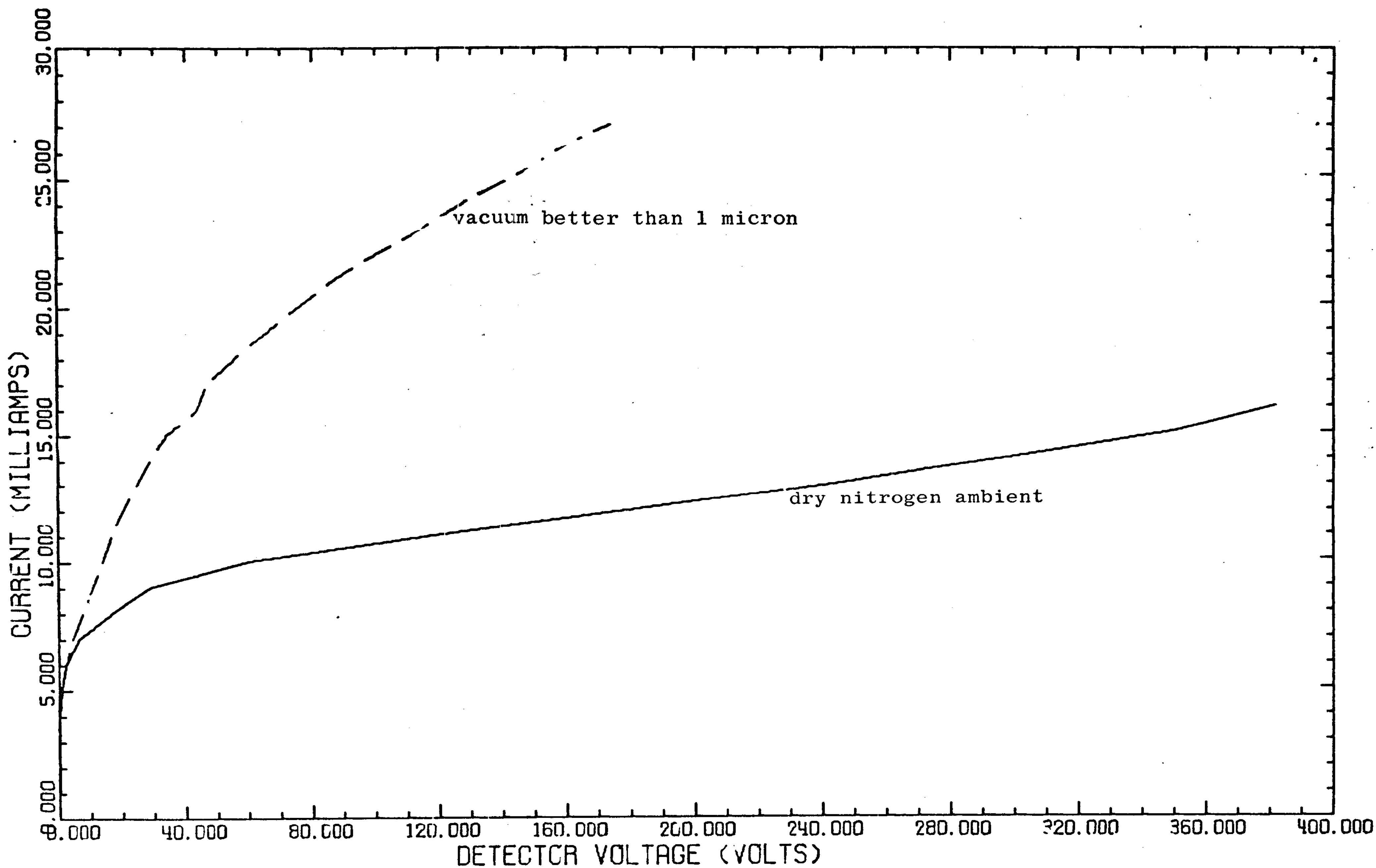


Fig. 2. Blocks for cooling annuli during drifting.



DIODE CHARACTERISTICS OF GE(LI) CYL#3

Figure 3

this. At constant current and temperature, the introduction of nitrogen makes the device a much better diode. Of course, the increased voltage reduces the drift time - an added benefit. We plan to drift in nitrogen (or a liquid) henceforth.

e) During the summer, we did a large amount of theoretical work on the response of solid state detectors. Much of the previously available work involves approximations which will be untenable for really large detectors.

This theory, which involves some very unusual differential equations, is now about half completed.

f) A liquid temperature-controlling drift apparatus is nearly finished. This more-sophisticated method should halve the drift time for a given volume of our detectors, or it should permit us to make larger detectors.

<u>Fabrication and Testing of Annular Detectors:</u>

a) The yield of two successful detectors in two attempts compares with three out of nine attempts for planar detectors. Partly this may reflect our improved techniques, but the low edge-to-volume ratio of the annulus, plus the apparent immunity to defects in the raw material would lead one to expect a higher yield.

b) About four and one-half weeks drifting time were required to reach $\sim 6\ cm^3$ volume in each of our annuli. A planar detector of the same volume would require 18 weeks under our drifting conditions. Either we can have the advantage of a much faster drift, or use a much cooler drift compared to planar detectors.

Figure 4a shows an end view of an annulus of 4 mm effective thickness.

c) Leakage impedance at liquid N_2 temperature is about 2000 megohms, compared with 10-20 megohms for our planar detectors.

d) The resolution started at $\sim$30 KeV and steadily improved. After two weeks it has reached 21 KeV. Figure 5 shows a Bi^{207} spectrum exhibiting this. This resolution, although it compares well with that of commercially available Li drifted Ge detectors is not equal to the best published results [3]. This reflects a deliberate choice on our part, since we intended to test the detectors with nuclear reaction spectra, which are heavily doppler-broadened, we decided to forego a clean up drift in order to expedite the tests. We are confident that a clean-up drift would have increased the resolution to the maximum theoretically obtainable with a detector of this depletion depth (4 mm).

e) Count rates $>$ 50,000 per second do not degrade our spectra. Figure 6 shows a gamma spectrum from 1-MeV deuterons on a F^{19} target. Twenty-seven different gamma lines have been identified on this spectrum. Using five other targets - B^{10}, B^{11}, N^{14}, A^{27}, and natural Si - we have observed 96 other gamma lines. Most of these lines are doppler-broadened to be from 30 KeV to 70 KeV FWHM. Hence, 20 KeV resolution is not a limiting factor in this type of nuclear work.

f) A 3-crystal pair spectrometer has been assembled which uses a 3" x 1" NaI detector on each side of the annulus. Using this, spectra from the above targets have been taken so that full-energy and escape peaks can be identified.

3) G. T. Ewan and A. J. Tavendale, Can. J. Phys. 42, 2286 (1964).

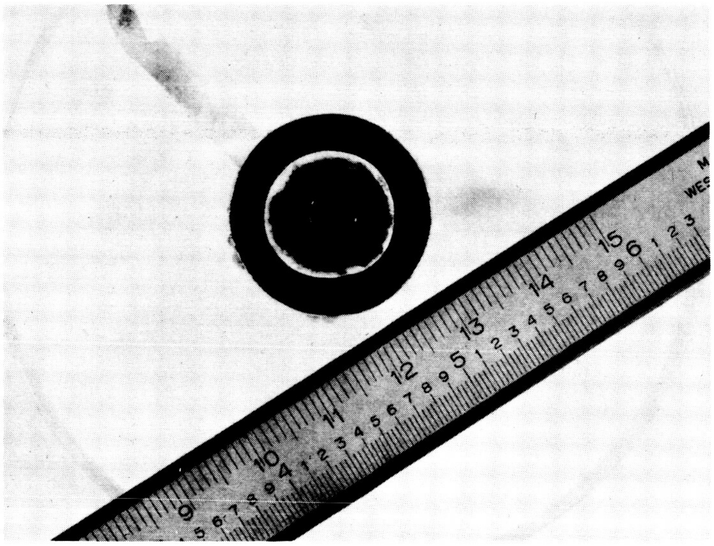


Fig. 4 a. Copper-stained end of annulus after partial drifting; 4 mm drift depth.

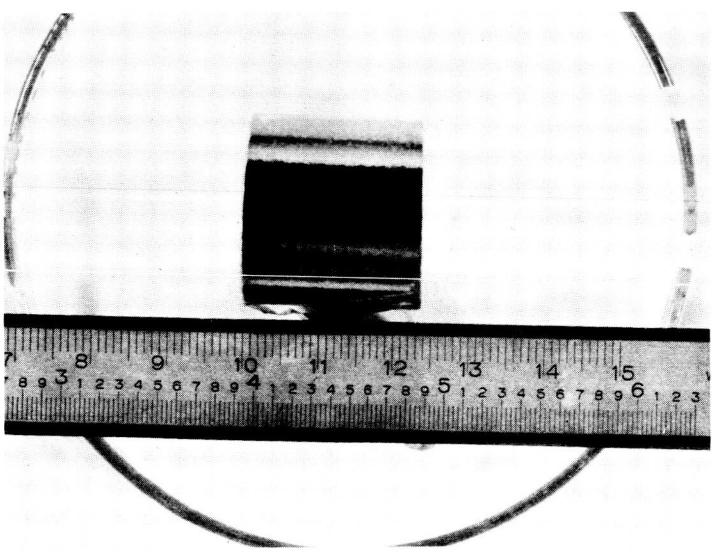
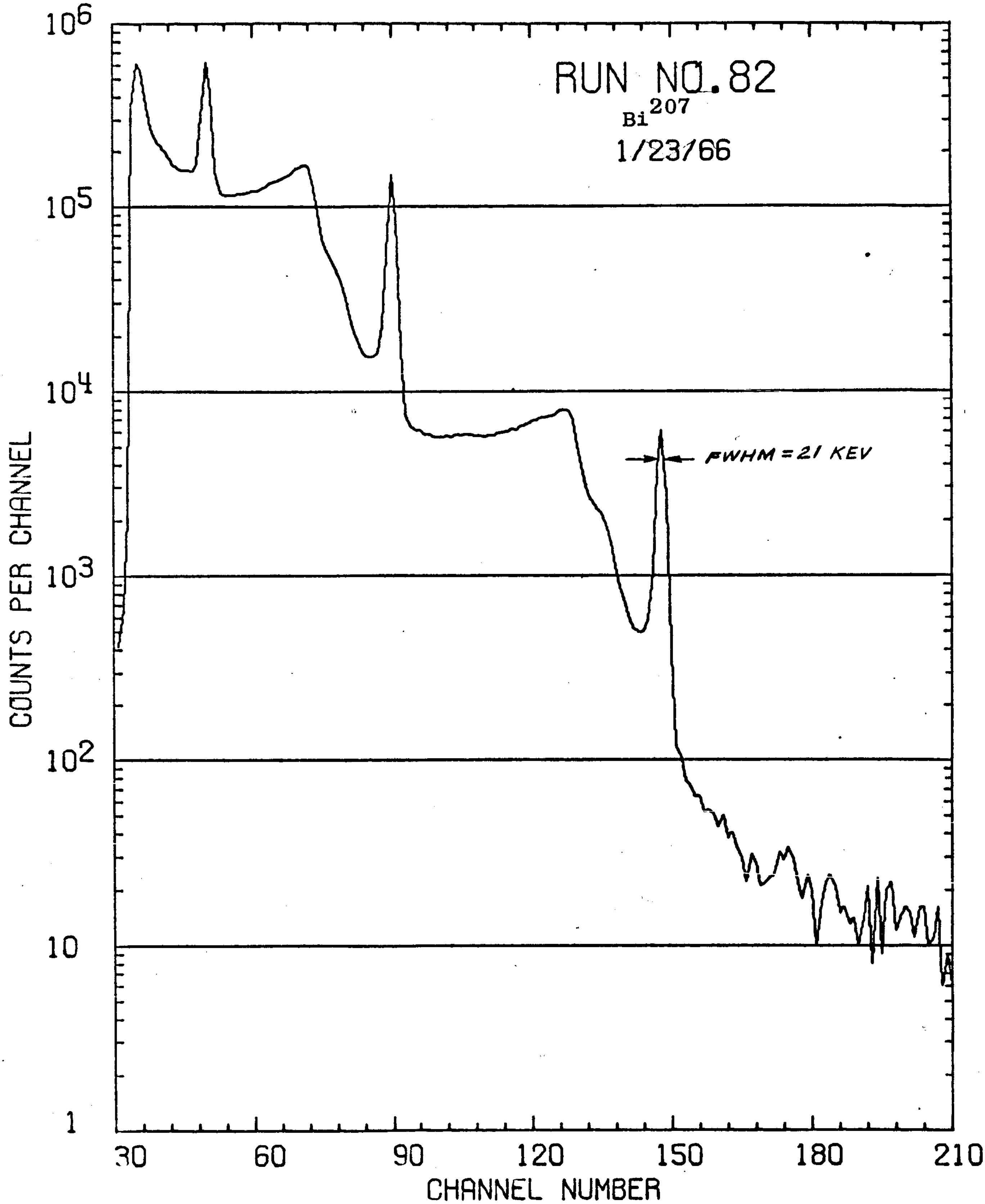
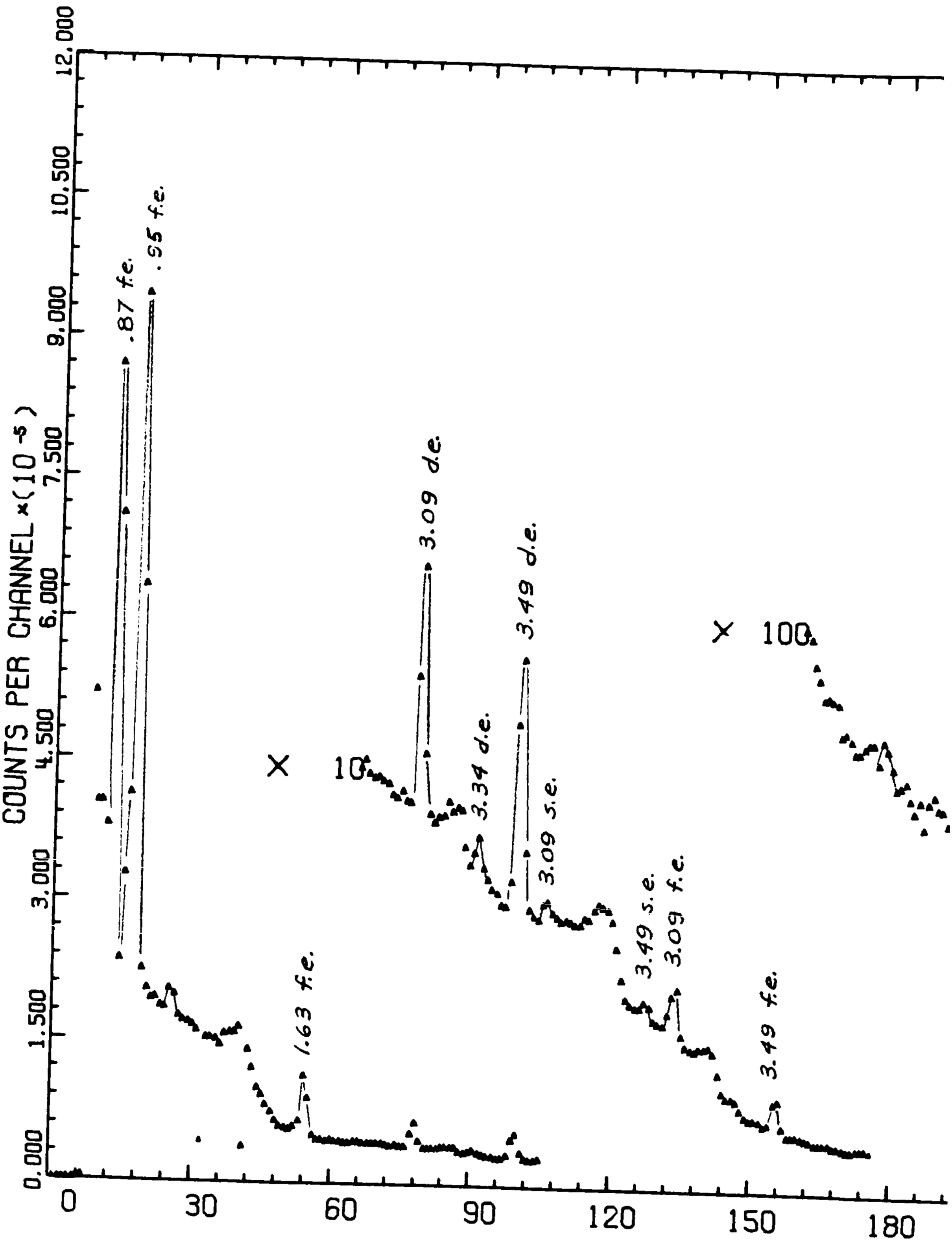


Fig. 4 b. Side view of annulus.



RUN NO.82
Bi207
1/23/66
FWHM = 21 KEV
COUNTS PER CHANNEL
CHANNEL NUMBER
10^6
10^5
10^4
10^3
10^2
10
1
30
60
90
120
150
180
210

Figure 5



COUNTS PER CHANNEL ×(10⁻⁵)
0.000
1.500
3.000
4.500
6.000
7.500
9.000
10.500
12.000
0
30
60
90
120
150
180
.87 f.e.
.95 f.e.
1.63 f.e.
× 10
3.09 d.e.
3.34 d.e.
3.49 d.e.
3.09 s.e.
3.49 s.e.
3.09 f.e.
3.49 f.e.
× 100

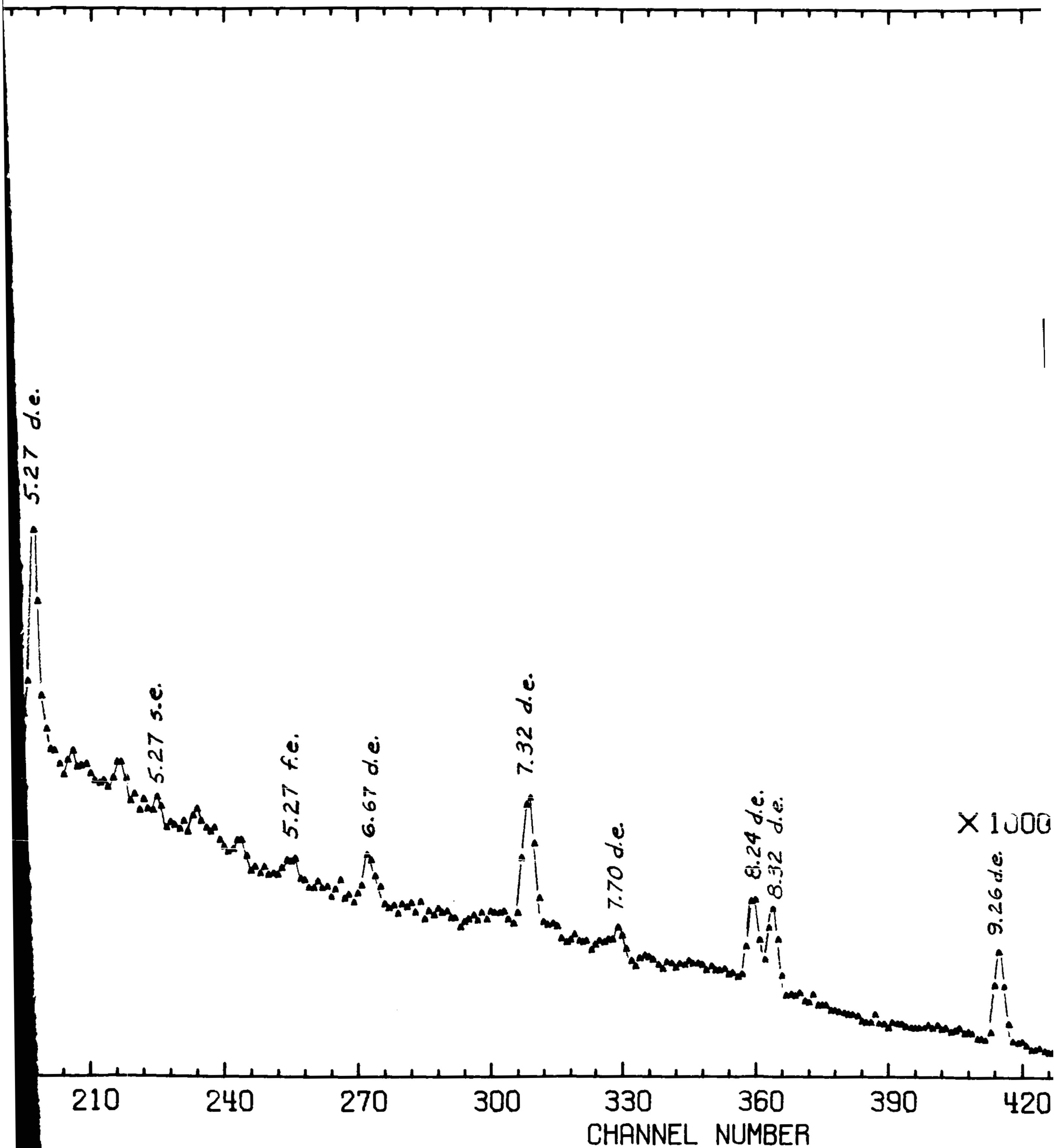


Fig. 6. Spectrum of $F^{19} + d$

g) Oscillograph measurements indicate that the pulse shape variation is very small. With commercial medium-fast crossover-pick off electronic equipment, we find something less than 30 n sec total time dispersion for pulses varying in energy from 0.5 MeV to 12 MeV. More quantitative tests are in progress.

h) As was mentioned above, there were serious defects in some of the raw material supplied by Sylvania which led to the failure of approximately 90% of the detectors manufactured by some major users. The nature of the defects in the raw material was unknown except that they occurred after the furnaces at the manufacturers plant had been rearranged. This led a member of this department* to suggest that the defects were axial dislocations typical of boat-refined material, which shorted out the axial detectors cut at right angles to the crystal axis. In our annular detectors these dislocations would be parallel to the depletion layer and therefore should have no influence on the detector performance. We are checking this possibility in cooperation with the manufacturer and hope that, if confirmed, our findings will lead to the manufacture of still larger detectors.

SUMMARY

New techniques for the manufacture of Li-drifted Ge detectors have been developed and employed to make large volume annular detectors. These detectors have the following advantages over planar detectors and five sided "co-axial" detectors.

*J. Mitchell, private communication.

a) Due to the fact that the depletion region is everywhere parallel to the axis of the raw crystal, dislocations introduced by the thermal stress during manufacture, should have no effect on detector performance. This is partly borne out by our lower failure rate in the manufacture of annular detectors, and will be investigated further.

b) Compared to planar detectors a much larger volume can be obtained with our annular design, also, the larger volume to surface ratio reduces edge effects.

c) Compared to "co-axial" detectors the annular detector has, due to its rotational symmetry, a more uniform sensitivity and a more uniform, and generally better, time resolution.